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IDA DOCUMENT D-815

THE DEVELOPMENT OF A LEVEL 4 VIDEODISC – AN ELECTRONIC PUBLICATION CASE STUDY

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August 1990

Prepared for
Office of the Assistant Secretary of Defense
(Force Management and Personnel)
and
Office of the Assistant Secretary of Defense for Public Affairs
(American Forces Information Service)

IDA
INSTITUTE FOR DEFENSE ANALYSES
1801 N. Beauregard Street, Alexandria, Virginia 22311-1772

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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
August 1990

3. REPORT TYPE AND DATES COVERED
Final--February 1990 to May 1990

4. TITLE AND SUBTITLE
The Development of a Level 4 Videodisc--An Electronic Publication Case Study

5. FUNDING NUMBERS
C - MDA 903 89 C 0003
T - T-L2-565 and T-Z2-629.6

6. AUTHOR(S)
Richard J. Vogel, Mary R. Marlino

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Institute for Defense Analyses
1801 N. Beauregard St.
Alexandria, VA 22311-1772

8. PERFORMING ORGANIZATION REPORT NUMBER
IDA Document D-815

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

OASD/FM&P	OASD (AFIS)
The Pentagon, Room 3B930	601 North Fairfax Street
Washington, DC 20301-4000	Alexandria, VA 22314-2007

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

This document discusses the background, purpose, planning, and production of a Level 4 videodisc to provide operating instructions and maintenance procedures for the U. S. Army's EIDS system. Although no inherent instructional differences between Level 3 and Level 4 videodisc formats were found, production of the Level 4 videodisc discussed here was found to be more complex and more time consuming than it would have been for a Level 3 production. However, replication and distribution of the instructional materials were found to be less costly for Level 4 than for Level 3 videodisc format. The authors recommend use of Level 4 videodisc format when large scale replication is required.

14. SUBJECT TERMS
Electronic Information Delivery System (EIDS), Interactive Videodisc (IVD), videodisc production, videodisc planning, electronic publication

15. NUMBER OF PAGES
58

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	SAR

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39-18
298-102

IDA DOCUMENT D-815

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Distribution/	
Availability Codes	
Dist	Avail and/or Special
A-1	

INSTITUTE FOR DEFENSE ANALYSES

Contract MDA 903 89 C 0003
Tasks T-L2-565 and T-Z2-629.6

FOREWORD

This work was performed to support Office of the Secretary of Defense initiatives to promote the portability of interactive courseware. This document is one of several that were written for Institute for Defense Analyses (IDA) tasks in courseware portability and were sponsored jointly by the Office of the Assistant Secretary of Defense for Force Management and Personnel and by the American Forces Information Service, Office of the Assistant Secretary of Defense for Public Affairs. Technical oversight was provided by LTC G.A. Redding, USA, of the Defense Audiovisual Policy Office, OASD/PA, and Gary Boycan of the Training Policy Office, OASD/FM&P. The IDA task leader for this work was J.D. Fletcher, Science and Technology Division.

ABSTRACT

This document discusses the background, purpose, planning, and production of a Level 4 videodisc to provide operating instructions and maintenance procedures for the U.S. Army's EIDS system. Although no inherent instructional differences between Level 3 and Level 4 videodisc formats were found, production of the Level 4 videodisc discussed here was found to be more complex and more time consuming than it would have been for a Level 3 production. However, replication and distribution for the instructional materials were found to be less costly for Level 4 than for Level 3 videodisc format. The authors recommend use of Level 4 videodisc format when large scale replication is required.

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ABBREVIATIONS

ASCII	American Standards Code for Information Interchange
CDI	Compact Disc Interactive
CD-ROM	Compact Disc/Read Only Memory
CVSD	Continuously Variable Sloop Deltamodulation/demodulation
DCF	Disc Configuration Frame
DOS	Disk Operating System
DTR	Digital Recovery Card
DVI	Digital Video Interactive
EDL	Edit Decision List
EGA	Enhanced Graphics Adaptor
EIDS	Electronic Information Delivery System
EP	Electronic Publication
IDS	Intermediate Direct Support
IR	Infrared
IVD	Interactive Video Disc
kB	Kilobytes
kHz	Kilohertz
NTSC	National Television Standards Committee
PC	Personal Computer
SC/H	Subcarrier Horizontal
SMPTE	Society of Motion Picture and Television Engineers
TBC	Time Base Corrector
VGA	Video Graphics Array
VGO	Video Graphics Overlay

EXECUTIVE SUMMARY

This document describes the background, purpose, planning, and production of the ***EIDS Electronic Publication*** Level 4 videodisc, the electronic manual which provides operating instructions and maintenance procedures for the Army's EIDS system. The videodisc was developed by MetaMedia Systems, Inc., of Germantown, MD, and was the first Level 4 interactive videodisc (IVD) to be produced under contract to Matrox.

For the purpose of this project, the MetaMedia design team developed a working description of Level 4 as containing the following elements:

1. All computer graphics are stored on the videodisc.
2. Digital data must be stored in a form that is recognizable by the computer as a standard Winchester hard disk format.
3. A disc configuration frame (DCF), which is used to calibrate the system so that it can correctly grab digital information from the videodisc, must be mastered on the videodisc.
4. Digital information must be stored in the video frames on the videodisc.

Both the instructional design and the programming of the ***EIDS EP*** were guided by several constraints which were set by the terms of the Department of the Army contract. These issues included multiple audiences, multiple versions of the system, multiple input devices, and the need for practice opportunities and simplicity of use. Although there are no inherent instructional differences between Level 3 and Level 4 videodiscs, the complexity of the design process for this ***EIDS EP*** was significant. Additional design issues included those of memory management, cache management, motion versus still frame video, still frame audio, retrieval of information, and disc geography. The issue of disc geography was found to be especially critical with Level 4. To reduce access time, the Winchester image was placed in the center of the disc, surrounded by the courseware. The motion segments were put at the beginning and at the end of the videodisc, and all of the still frame segments were grouped together and laid out around the videodisc. Black buffers were placed around the digital information, because of the likelihood of the necessity for changes to some of the audio and digital information.

Upon review of the requirements for the ***EIDS EP***, OASYS and PILOTplus were selected as the best solutions for programming. EIDS ASSIST, the Army's authoring system, was not yet available when work began on the ***EIDS EP***. The MetaMedia team identified twelve essential capabilities for an authoring language or system to function fully on Level 4, in addition to the critical issues for performance, ease of use, and the ability to make changes or additions to the courseware.

Many of the management issues encountered by the MetaMedia team during the course of this project were related to the newness of the medium. Constant revisions, a steep learning curve, production obstacles, and software integration issues unique to producing the first Level 4 videodisc were encountered. In order to determine the general cost issues surrounding the production of a Level 4 interactive videodisc, the production tasks were broken down into the categories of common tasks and additional tasks. Common tasks were defined as those that are common to both Level 3 and Level 4 development, but, because of the complexity of the Level 4 videodiscs, take longer to complete. These include design, scripting, allocation of disc geography, the compilation of the edit decision list, pre-mastering, and programming. Additional tasks were defined as those that were unique to Level 4 development. They include: digitizing and editing the digital audio, developing the digital edit decision list, and pre-mastering the digital information. The primary significant difference for material cost for Level 4 was the additional check discs which were required during the development process. It is recommended that a minimum of two check discs be produced during the development process; one for all of the visuals and digital audio, and the second to contain the Winchester image and which will operate as a Level 4 disc. Two additional cost issues should be considered in light of the final product. Although the production costs of Level 4 are higher than Level 3, the information storage capacity is also larger. The second factor to be considered is the cost savings in distribution. Since floppy diskettes are not necessary in self-contained medium such as Level 4, distribution costs can be reduced considerably. Although not all applications would be appropriate for Level 4 development, in large distribution systems for one or several courses the production costs of Level 4 might be justified.

Resources for the development of Level 4 are also more extensive than those required for Level 3. It is recommended that all of the production team members have some experience in the production of Level 3 videodiscs before embarking on a Level 4 project. The minimum recommended equipment configuration is an EIDS Version 3 or

Version 6 and a pre-mastering upgrade option with at least 80 megabyte hard drive. Equipment needs will vary, depending on whether an in-house studio facility is available and complexity of the project. If no in-house studio facility exists, Matrox can provide developers with a digital pre-mastering service for around a $1,000 a day.

Based on the experience of developing the ***EIDS EP***, MetaMedia believes that Level 4 technology is an appropriate choice for mass replication because of the density of information which can be stored and the capability to run the program directly from the videodisc. It is anticipated that future development efforts will be less time and cost intensive, and that Level 4 technology is a viable transitory medium to the coming digital era.

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I. INTRODUCTION

The purpose of this paper is to document the design and development of the ***EIDS Electronic Publication (EP)*** Level 4 Interactive Videodisc, developed by MetaMedia Systems, Inc., of Germantown, MD. Since MetaMedia was the first contractor to develop a Level 4 videodisc, the lessons learned and the design and production recommendations that have resulted from this experience should be of particular interest to instructional designers and other third party vendors who are interested in EIDS-compatible products and services.

A. BACKGROUND

EIDS (Electronic Information Delivery System) is an Army stand-alone computer-based instruction and interactive video delivery system for education and training. The system was developed by the Army to address the critical need for efficient and cost-effective methods of training. The ***EIDS Electronic Publication*** provides almost instantaneous access to instructions and information on how to operate and maintain the EIDS system. It was designed to replace the traditional paper manual which would ordinarily accompany a new piece of operating equipment. The videodisc was also developed to demonstrate and exploit the unique features of the EIDS system. It is the first videodisc "electronic training manual" in use by the military, and will accompany every EIDS system delivered.

B. THE PURPOSE OF THE *EIDS EP*

The purpose of the ***EIDS Electronic Publication (EP)*** is to explain and demonstrate the purpose, the operation, and the training potential of EIDS to a variety of users. Matrox, the EIDS developer, is interested in demonstrating that EIDS is appropriate not only for training, but also for information delivery. The primary goals of the ***EIDS EP*** are:

- To facilitate the use of EIDS hardware by different types of users;
- To identify the positive implications of EIDS for training;

- To illustrate the potential uses of videodisc simulations for military training; and
- To provide information on maintenance procedures and access to EIDS equipment self-tests and utilities.

C. LEVEL 4 INTERACTIVE VIDEODISCS

Although there is certainly no shortage of definitions for Level 4 videodiscs, in the course of developing the ***EIDS EP,*** the MetaMedia design team developed a working description of Level 4 as containing the following elements:

1. All computer graphics are stored on the videodisc.
2. Digital data is stored in a form that is recognizable by the computer as a standard Winchester hard disk format.
3. A disc configuration frame (DCF), which automatically calibrates the system so that it can correctly grab digital information from the videodisc, is mastered on the videodisc.
4. Digital information is stored in the video frames on the videodisc.

Level 4 can thus be defined as an interactive application that requires both standard video and digital information encoded in the video field. This digital information can be downloaded into the computer and decoded as either still frame audio, graphics, or digital data required to run the program. This process of recovering digital data from the videodisc allows an entire application to be self-contained on the videodisc. The application does not require the use of floppy diskettes to run the program. Users simply insert the videodisc into a player and turn on the computer. The program boots and operates directly from the videodisc. The videodisc becomes a read-only optical drive and runs entirely under the DOS operating environment.

Digital information in a Level 4 videodisc is stored in the videodisc frames. To record digital information, video frames are encoded with either black or white pixels; each pixel represents one bit. An NTSC signal is composed of 376×484 pixels, giving a total of 22,748 bytes of raw digital data per frame without any error correction. Because there may be horizontal shifts in the video frame, the first three and the last four of the 376 columns of each frame are left blank to compensate for these shifts without data loss (1 pixel on the horizontal axis = 1 column). This leaves an area of 369×484 pixels, or 22,264 bytes per frame for user data.

Because the videodisc is an analog storage medium, there must be some error correction scheme available to properly retrieve this digital information. On a Level 4 videodisc there are two error correction schemes to retrieve digital information from the videodisc. The first, the single pass method, is used primarily for digital audio, and has an error rate of one bit per million. Each frame of video can store up to 16.2 kB of digital information. The second, the double pass method, allows for the maximum error correction. It has an error rate as good as a fixed magnetic hard drive, about one error in 10^{12} bits, and storage capabilities up to 11.5 kB per frame (see Figure 1). Double pass error correction is used for the Winchester image, which is an exact copy of the hard drive, including all the partition information; this image is mastered on the videodisc. This image usually comprises the computer control program, drivers, disk operating system, and any utilities required for the program. When 20 copies of the ***EIDS EP*** were mastered, Matrox found an error rate that was better than that of a hard drive, one error in 10^{19} bits.

Density	Bytes/Frame	Error Rate
Single Pass	16,192	10^7
Double Pass	11,776	10^{12}

Figure 1. Digital Data Error Rate for Level 4 Videodiscs

In the double pass method the compression rate of digital data is high, allowing for a relatively large Winchester image on the videodisc without using excessive real estate. For example, the Winchester image can store up to 40 megabytes in about 3,745 frames (about two minutes of video).

When the digital information is grabbed from the videodisc, it is stored in a cache buffer within the PC made up of 16 frames (each frame is 16 kB). The default setting in software allows the first eight frames to store digital audio, and the last eight frames to store the Winchester information. This division can be changed through software. The default cache of 8 frames delivers performance similar to that of a 20 megabyte hard drive (see Figure 2).

Format	Capacity (kBytes)
Raw (no correction)	21.742
Single Pass	15.813
Double Pass	11.500

Figure 2. EIDS Digital Capacity per Frame

The digital audio record and playback uses continuously-variable-sloop-delta-modulation/demodulation (CVSD), and can be processed at three different levels of quality. Audio quality is defined as signal-to-noise ratio, distortion, and dynamic range, and is directly related to the clock frequency. Consequently, more audio can be stored per frame buffer at the lowest quality (lower clock frequency) than at a higher quality (higher clock frequency). The available bandwidth for all the different clock frequencies of audio is 4.5 kHz. This bandwidth is more than adequate for the speakers on the EIDS hardware. The ***EIDS EP*** uses medium quality audio. The highest possible quality of audio requires 2.03 seconds per frame buffer. Based on a 16-frame buffer, it is possible to hold up to 32.42 seconds of audio for playback at any given time. Storage capacities range from approximately 29 hours of high quality audio, to 40 hours of medium quality audio, to 60 hours of low-quality digital audio on a single videodisc side (see Figure 3).

Quality	Speed	Clock, kHz	Sec/Frame	Max. Time, sec	S/N Ratio, dB
High	0	63.9	2.03	32.42	36
Medium	1	45.3	2.86	45.74	34
Low	2	32.0	4.05	64.85	30

Figure 3. EIDS Digital Audio Speeds

The DCF is mastered on all Level 4 videodiscs in frame 1001. Because of the physical anomalies of a videodisc, the first 1,000 frames have smaller pits, less reflectivity, and a higher susceptibility to potential problems such as over modulated video and dropouts. Frame 1001 was chosen because it would avoid potential problems in reading the digital information in the DCF. This frame is the most crucial frame of digital data on the videodisc; it is used to calibrate the system automatically so that it can correctly grab the digital information from the videodisc. It also contains the videodisc identification number, and the location of the Winchester image. Without it, the videodisc will not work as a Level 4 disc.

D. FUNCTIONAL DIFFERENCES BETWEEN LEVEL 3 AND LEVEL 4 SYSTEMS

The functional differences between Level 3 and Level 4 are directly related to the process by which digital information is digitally encoded on the pre-master videotape and decoded off the mastered videodisc. This new technology expands the current capabilities of the videodisc medium and brings about a new level of IVD, called Level 4. This new level has extended the capabilities of IVD, but there are definite advantages and disadvantages for using Level 4 over Level 3. Outlined below are the functional differences between the two levels. They include the following:

1. A Hybrid Medium

The most significant functional difference between Level 3 and 4 videodiscs is the amount and type of data storage capabilities afforded by a hybrid videodisc. The hybrid videodisc allows computer-readable digital information to be stored in DOS format on the videodisc, which can be accessed by the computer just as it would a DOS file on a magnetic disk. The main difference between this hybrid medium and a magnetic disk is that it is a read-only medium and only allows the digital information to be recalled (read) but not amended or recorded (written). Information on a magnetic disk can be both read and written. The resulting information storage resource allows huge data bases and/or multiple courseware lessons to be recorded on a single disc. Both levels of videodisc can present information to users in a multimedia fashion. In Level 4 applications, video information can be in the form of graphics, text, digitized images, still-frame pictures, or animated motion sequences, and can be accompanied by an audio soundtrack. Computer-generated graphics can be used independently, or can be overlaid on a videodisc-based picture. In addition, computer-controlled audio can accompany any video sequence, including soundover-still presentation sequences. In a hybrid videodisc, analog and digital information can be mixed in any proportions on the disc on frame-by-frame boundaries. In Level 4, it is possible to have both tracks of analog audio and up to 60 hours of digital audio. As a digital storage medium, each frame on the disc can store up to 16 kB of digital data. A single videodisc can therefore hold up to 600 megabytes of information (see Figure 4).

Types of Information	Level 3	Level 4
Motion Video	30 minutes	30 minutes
Audio	1 hour	60 hours
Digital Data	None	600 MBytes
Still Frames	54,000 Frames	54,000 Frames

Figure 4. Capacity of Information

2. Installation and Distribution

The digital compatibility of Level 4 allows all of the courseware to be self-contained on the videodisc, rather than on secondary storage media such as floppies or a hard drive. Level 3 courseware has to be stored on separate media, whether it is on CD-ROM, hard drive, or floppies. This makes distribution and installation more complicated for Level 3 than for Level 4. These installation programs range from very simple, auto-install programs to complex programs that require extensive knowledge of an operating system like DOS. These installation programs, whether they are simple or complex, require some knowledge of an operating system. They also leave room for mismatch of media and incorrect installation. Mismatch of media can occur when a course contains several floppies and multiple videodiscs, a very common distribution method in the industry. There are no industry-wide standards for determining the correct videodisc side for the courseware in use. In addition, there is no standard method for ensuring whether the correct disc is matched to the correct courseware. Various methods in use include using autostops (not supported on all systems using), special videodisc I.D. numbers (not supported by all videodisc players), and visual I.D. (highly susceptible to operator error). When using a Level 4 videodisc, there is no installation program. The user simply places the videodisc inside the EIDS system, closes the videodisc drawer, and turns on the system. The courseware starts automatically. With Level 4, even with multiple discs, there is no need to ensure that the correct disc side is inserted or that the correct disc is matched to the correct courseware. A simple text file can be accessed on each disc. This text file contains the information necessary for the computer control program to automatically match the correct disc I.D. and side.

3. Durability of the Media

Durability of the media is another functional distinction between Level 3 and Level 4 technology. With Level 4, all components of the courseware are stored on the videodisc, which has proven to be a very durable medium. Level 3 programs are less durable because the computer control programs are generally stored on magnetic media like floppies and are more susceptible to damage from magnetic fields, fingerprints, and spills.

Videodiscs are not as sensitive as floppies to environmental factors, but they can be damaged. Videodiscs can be subject to warping in very hot, humid climates, or if they are stored horizontally on uneven surfaces instead of vertically. They are also vulnerable to videodisc "rot." This occurs because moisture has seeped between the plastic and the aluminum surface, causing a chemical reaction to occur in the adhesive. This problem is less likely to occur today because of the improvements made in the bonding process. New adhesives are being used to prevent videodisc rot. Another innovation which will be used in the future for videodisc manufacturing is a single molded plastic disc. Currently, manufacturers use a "2P" process and bond the two plastic plates between the aluminum surface. Using the single molded process used in CD manufacturing will eliminate the rot problem.

In terms of the reliability of the digital data on a videodisc versus a floppy, videodisc is a more reliable medium. The data on a read-only medium such as a videodisc cannot be corrupted by viruses, erased, or overwritten, unlike a floppy. The error correction schemes on Level 4 videodiscs make the error rate per bit of data equal to that of a hard drive.

4. Ability to Update

Many factors such as correcting bugs, and changing subject matter, require that courseware be updated in its life cycle. This is true for both Level 3 and Level 4 courseware. In Level 3, courseware is updated by either floppy disks and/or another mastering of the videodisc, depending on the type and extent of the update.

The same is true for Level 4. Level 4 can be updated in two ways. The first way is by using a magnetic update via floppies or a hard drive. The *EIDS EP* used this method to fix a problem with the drivers. A floppy diskette containing an updated driver was placed in the floppy drive. There are 1.4 megabytes available from both floppy drives and even more with a hard drive. Level 4 can read data from either medium. The second method is by re-mastering the videodisc. The only difference between a Level 4 and a Level 3 with regard to updates is the additional step required for Level 4: mastering the digital information on the pre-master videotape, if enough changes in the digital information require mastering a videodisc.

5. Transportability of Courseware

There exists a variety of vendors for Level 3 systems (e.g., Sony, IBM, Visage, VAL, Videologic, Online and Matrox) but there exists only one vendor for Level 4, Matrox. A Level 3 system usually consists of an IBM compatible computer, an overlay board, a graphics card, touch screen interface card, related cables, and a videodisc player. There are no industry-wide standards for Level 3 hardware; for this reason, transporting courseware from one vendor's system to another is often indirect and sometimes very difficult. Some vendors offer "emulation" programs so that other vendors' software will run on their system. However, there are still problems with transporting software across hardware platforms. These problems include colors (color maps) that vary in intensity and hue, and various video overlay boards which do not support the same special features, such as video fading. Additional problems occur when the positioning of text and graphics varies slightly, especially when touch points are close together and partial graphics and text must be overlaid in an exact "x, y" position.

A Level 4 system is also non-standard and specific to a vendor. The commercial version consists of an IBM compatible AT, a VGO-AT compatible overlay board, a DTR-AT board, related cables, and a videodisc player. Transporting Level 4 courseware to other vendor's systems is not possible because Matrox's encoding and decoding scheme for digital information in the video frame is proprietary. The DTR-AT board in the Matrox commercial IVD system is what distinguishes it from a Level 3 system. This board enables the delivery system to decode the digital information from the videodisc, and costs around $1,000. Matrox has the largest installed base of IVD hardware in the country (12,000 systems) and can support both Level 3 and Level 4 applications. Its availability does not present a problem at this time.

In order to encode the digital information onto the videotape, special proprietary hardware and software are required. Matrox bundles this software and hardware into a "Pre-mastering Upgrade Option" for around $7,000. This option provides a developer with the capability of encoding the digital information directly onto a one inch pre-master videotape. Matrox also offers a service to digitize the digital information for a developer for approximately a $1,000 a day. The ***EIDS EP*** required six hours to master all of the digital information onto the pre-master videotape, and an additional two hours to develop the edit decision list (EDL) for the pre-master software.

6. Extended Audio

Level 4 technology offers over 60 hours of audio per disc side, a capability that Level 3 does not have. This capability allows a courseware developer to use extended audio for more complete feedback, longer presentations, and better explanations. With a Level 3 system, the presentation of a single picture with 30 seconds of audio would require 30 seconds of motion video on the disc. This is not the case for Level 4. With Level 4, 30 seconds of audio for a single picture would require (at medium quality) 12 frames on a videodisc, instead of 900 frames in Level 3. With this capability, a 20-hour course that would take 10 disc sides to produce in Level 3 would only take one disc side on Level 4 (this assumes the Level 3 courseware uses one hour/disc side of audio, a majority of single frames, and some motion).

II. INSTRUCTIONAL DESIGN FACTORS FOR LEVEL 4 IVD

General Instructional Issues

Instructionally, there are no significant differences between Level 3 and Level 4. Level 4 is simply a much more efficient storage medium than Level 3 videodisc. The design of the ***EIDS EP*** uses several instructional strategies that are common to both Level 3 and Level 4 to satisfy the requirements set forth by the Army. These issues included multiple audiences, multiple versions of the system, multiple input devices, and the need for both practice opportunities and simplicity of use.

A. MULTIPLE AUDIENCES

The ***EIDS EP*** was organized to meet the needs of a variety of users, specifically:

1. First Time Operators/Users

The disc was designed so that the first time user would be given sufficient information to use all of the EIDS interactive features and accessories. Immediate operator orientation to the system was determined to be crucial for these users. To meet this need, an orientation section was provided that presented a short linear sequence that explained how to interact with the ***EIDS EP***. Two versions, each tailored to a specific EIDS model, were produced. If the user is already familiar with the ***EIDS EP***, he or she has the option to touch the NEXT icon to skip through this section.

2. Other Operators/Users

Any section of the ***EIDS EP***, including those designated specifically for first time users, should be able to be accessed by other operators/users. It was determined that quick access to the required information was crucial. To meet this need, a hierarchy of menus was designed to help users access any information within the ***EIDS EP*** quickly and efficiently.

D. PRACTICE OPPORTUNITIES

EIDS EP was designed to allow the operator/user to practice a simulation representing a 2-D task common to setting up or operating EIDS.

E. USER INTERFACE

Because of the large number of still pictures in Level 4, it was especially important that they be of excellent quality in order to maintain user attention and to avoid distraction. One important use of visual design principles is to direct the student's attention and to stimulate interest. Because of the exceedingly large amounts of information which are available to users in Level 4 IVD, the issue of selective perception is an especially important one. Factors and guidelines that were considered by the MetaMedia design team as contributors to good visual design for still frames included:

- Present one idea per screen
- Avoid cluttering the screen with too much information
- Use a small number of type styles and sizes to highlight ideas
- Use color sparingly for cueing or emphasis and avoid extreme contrasts
- Organize information functionally on the screen as much as possible to reduce confusion and unnecessary cognitive processing
- Use graphics and visuals instead of text whenever possible.

F. ORGANIZATION

Because of the massive storage capacity of Level 4 videodiscs, the risk of the user getting lost and being unable to find specific sequences is high. A great deal of attention must be paid to the organization of the information on the videodisc and to the provision of navigational aids.

A major organizational consideration of the *EIDS EP* was the user interface, which was intended to be suitable for both first-time and experienced users. A "default" path, which was designed so that new users could get to the information as efficiently as possible, was incorporated into the program. Many details and alternative paths of this disc will probably not be experienced by initial users. However, it was anticipated that as users became more comfortable with the videodisc, they would want to take shortcuts and explore more complex learning strategies.

Learner control options, which allow the user to back up, step ahead, get help, and return to the main menu, provide the experienced user with ways to take shortcuts or to get more details. They are also important in allowing the user to feel in control of the system, and are a critical aspect in achieving a high level of participation in the videodisc.

The instructions given to the user cover both the operation of the videodisc as well as how the material is structured on the disc. It was anticipated that many of the users of the ***EIDS EP*** would have had little experience with self-study learning, and would need some level of orientation.

G. ACTIVE PARTICIPATION

EIDS EP was designed to allow the user to control the pace, the instructional strategy (e.g., tutorial, simulation, test, etc.) and the "depth" of instruction. Active participation by learners is closely related to positive learning outcomes, and can be achieved by novel information presentations and the relevance of the instruction to the intended audience. The MetaMedia design team incorporated several design strategies intended to encourage active participation with the ***EIDS EP***, such as the use of the scoreboard routine.

H. METAPHORS

In the ***EIDS EP***, the organizational metaphor of a book was chosen to parallel the concept of an "electronic manual" with a traditional paper manual. Just as a traditional manual is organized into chapters, the ***EIDS EP*** is also divided into chapters, sections, pages, paragraphs, and topics. In addition, the metaphor of a bookmark is also employed to display and store page numbers for later retrieval. The bookmark can serve as an "advance organizer" in providing the following information: current chapter, current section, current topic, current page number.

I. GENERAL SCREEN DESIGN GUIDELINES

Every effort was made during the design phase of the ***EIDS EP*** to adhere to a consistent design standard. Standards were set for the touch screen procedures and the screen layout with the following guidelines:

1. Touch Screen Procedures

Every time a specific screen location is u-ed, the exact same predictable action must occur.

2. Screen Layout

Consistent relationships, placement of identifying information such as titles, headings, instructional information, visual cues, and touch points must be apparent to the user. The design team worked with the following set of screen design guidelines:

a. Consistent relationship between headings and captions.

b. Consistent placement of common or frequently occurring information.

c. Consistent physical characteristics, e.g., size, color, font/typeface, and other typographic attributes.

d. Predictable rhythm or action of timed elements in video and frame to frame.

e. Audio consistency in volume and pitch.

f. Appropriate selection of words to match predetermined readability levels.

g. Well balanced visual and audio media mix in motion, stills, audio segments, etc.

J. COURSE MOBILITY

In addition to the pictorial elements of the user environment listed above, the element of course mobility must also be considered when designing for Level 4 IVD. The continual availability of a "Help" or "Next" option in each frame provides accessibility to extended course mobility via an expanded menu of options. The practical implementation of this tool provides the user with a high degree of movement within the learning environment. Though an instructional framework may be complex in nature, its complexity can be reduced by (1) a well ordered system of branching, and (2) a complementary menu system that can provide easy and regular access to all key locations in the learning environment with an electronic bookmark placed for easy return.

III. THE DESIGN PROCESS FOR *EIDS EP* LEVEL 4 IVD

Designing for Level 4 videodiscs is significantly more complex than designing for Level 3. As with Level 3 design, careful planning is very important, but even more so for Level 4 applications. There are more elements that must be considered in Level 4. When developing a detailed design document or treatment, it is necessary to consider how the program will work in a Level 4 environment. Several issues merit discussion as they relate to Level 4 disc design:

A. MEMORY MANAGEMENT

EIDS hardware comes with either 512 kB (Versions 1-4) or 640 kB (Versions 5-6) of memory. The ***EIDS EP*** is required to be backwards compatible, which means it has to work on the lowest common denominator of 512 kB of memory. If 640 kB of memory were available, then memory management would not be as much of a design issue. With 512 kB, when the application program is loaded with all of its drivers, less than 200 kB of space is available to run the application. Consequently, the ***EIDS EP*** had to be designed to allow for these space requirements.

A modular approach to the program addressed this problem. Logical breaks in the program flow were identified as points to download computer information. In Level 4 technology, when any digital information is accessed on the videodisc, the display screen goes blank until the information is completely downloaded. This blanking can vary from a barely noticeable interval to many seconds, and is primarily dependent on the efficiency of the design. It is caused by having only one videodisc head available to read both digital and analog information.

Consequently, if the computer must constantly access the videodisc for digital data, the program flow is disrupted. The ***EIDS EP*** was designed to download information at various key points to help minimize the disruption of the program flow.

One of the important features of the ***EIDS EP*** is the constant use of graphic overlay (required by the user interface designed for the system). In this small memory environment, the graphics had to be loaded in an animation buffer (128 kB) before each segment. This graphic downloading took approximately 15 seconds. Because of the time factor for downloading, five key breakpoints in the program were designated to be the area for downloading these graphics. These key breakpoints are at the start of the program, at the start of each chapter in the Operator's Manual, and at the EIDS Self-tests. These five points within the program were selected because they were natural breaks and would not interfere with the user branching within that point in the program. If the ***EIDS EP*** has been designed for a 640 kB system, there would have been no need to break the program up into logical points for downloading of graphics.

Also, program segments needed to be small enough to fit into available memory after all drivers and graphics were loaded. To address this problem, the program size for each segment was kept to around 32 kB. The decision to make these segments short was made before scripting. The outcome of this decision is that each segment is downloaded into memory before it begins. This allows the program to download an entire segment into memory, instead of accessing the Winchester image within the segment several times. As a result, the downloading of digital information takes an average of two seconds, and there is no noticeable disruption of program flow.

An additional issue which had to be considered was the implementation of ten bookmarks required for the ***EIDS EP***. This was a definite challenge with less than 200 kB of space. The bookmark feature was designed to keep track of the user's location within the program at all times. If the user selects the bookmark option, the current page of information is displayed on the bottom of the bookmark menu screen. This information contains the unit, section, paragraph, topic, and page number. The user can place up to ten bookmarks and access them from the bookmark menu. By touching the information option on the bookmark menu, the user can access information about any bookmark, which is displayed at the bottom of the screen.

The bookmark menu is an entire sub-menu structure within the ***EIDS EP***. Because the user can access the bookmark feature anywhere within the ***EIDS EP***, all of the information has to be maintained constantly.

B. CACHE MANAGEMENT

Cache management is the process of determining the optimum use of the 16 frame buffer (256 kB) when running any application program. This 256 kB buffer is on the digital recovery card (DTR-AT) and system memory does not affect the performance of this buffer. It is primarily used to help speed the transfer of data from the videodisc.

When using both digital audio and digital information from the videodisc, the issue of still frame audio length versus system performance is a necessary trade-off. The best length for an audio buffer is the default length of eight frames, which will provide eight frames for digital information, therefore giving optimum system performance. These buffers can be changed under software control to allow for sections with 16-frame audio sequences. The design issue here is to use the 16-frame buffer wisely. However, still frame sequences that require the full 16-frame buffer should be kept to a minimum. The more cache buffer that is available, the better the performance of the Level 4 program. A tactic to consider here is to find the optimum length in a still frame sequence and attempt to maintain this length throughout the entire program. The ***EIDS EP*** uses the default buffer. The average length of the digital audio in the ***EIDS EP*** did not exceed three buffers (8.64 sec). There are some digital audio events that are 14 frames in length but these audio events did not affect the cache buffer. If audio events rarely exceed the default of eight buffers, then system performance should not be affected.

C. MOTION VERSUS STILL FRAME AUDIO

The decision to use motion or still frames is another important Level 4 consideration. The MetaMedia design team decided to use real time motion to show how a particular procedure and/or equipment works in operation, or to show the relationship among moving parts. Stepped stills were used in cases where the user can benefit from seeing an action in small steps from various angles, or when critical steps require visual clarification. The ***EIDS EP*** required 24 minutes of real time motion and two hours of digital audio, using 900 still frames in stepped still sequences.

D. USING STILL FRAME AUDIO

When designing segments for still frame audio, it is helpful to consider the use of still frame audio in two ways. A single event can be loaded into the buffer and a series of stills can be stepped through by timing the audio event. A second possibility is to load the audio event and play it over a single still. These decisions are based on how much audio is necessary for a given sequence, and how that information is being presented. There are only 16 frames of audio that can be loaded into the audio buffer at a given time. For example, if medium quality audio is being used, only 45 seconds of audio can be played back at a given time. Therefore, if the audio is greater than 45 seconds, it must be broken into two or more events. However, every time the computer grabs a new digital audio event, the screen goes blank. It may indeed be better to design short, concise audio segments to reduce the amount of times it is necessary to grab the audio. The MetaMedia design team decided to develop a standard convention when using still frame audio in the ***EIDS EP***. This convention established a general rule-of-thumb that an audio event over a single still would be used if each still frame represented a different concept, and a single audio event timed to a series of stills would be used when a single concept could be best shown by displaying a series of stills.

E. SAVING INFORMATION FOR LATER RETRIEVAL

Another design decision concerns how to store information while in a Level 4 environment. In this environment, all of the digital information is read from the videodisc, not from a hard drive or floppy diskettes. Thus, the videodisc becomes a read-only optical drive. If any data is to be stored, it has to be stored on magnetic media, such as a hard drive or floppy diskettes, or in system memory. The resulting design issues are: how much data is to be stored, when will the data be stored, where the data will be stored, and how the data will be retrieved. In order to retain any data in a course for later retrieval, it has to be stored on magnetic media, such as a floppy. For instance, a courseware management system may require complex tracking of a student's responses and locations within the course. This type of tracking requires storage of data for later use by instructors. In order to perform a sophisticated tracking of student's responses, all data must be stored in system memory or on magnetic media. There is limited room in system memory to store data such as variables and strings. If the course is broken into segments, the memory requirements are not an issue. Each segment can be left in system memory until the user finishes that segment. When the user finishes the segment, the program can save the data that is in the system memory to a data file on floppy diskette. This data can be retrieved from the data file later. The ***EIDS EP*** stores all data in system memory. This data includes the 10 bookmarks, the checkmarks which indicate if the user has completed a segment, and the type of user. If the user leaves the system, all data is lost. The decision to store data in system memory was made because there was no requirement for retaining data for later use.

F. DISC GEOGRAPHY

The process of developing the disc geography for this Level 4 videodisc was a time-consuming and tedious task. Since this was the first time anyone had laid out a Level 4 disc, there were a lot of unanswered questions. These included:

1. Can there be two Winchester images on the videodisc?

The answer is no. There can only be one Winchester image on the videodisc. Because of this limitation, the Winchester image was put in the center of the disc. The courseware was designed to fit around this image, giving optimum disc access from anywhere within the program.

2. Can the audio be loaded before a series of stills, and the stills stepped through in sync to the narration?

This can in fact be done. One of the advantages of using this approach is that the presentation of visual information appears more seamless. Because the answer to this question was not known at the time the disc geography was laid out, a more conservative approach was taken: to lay down the digital audio with each slide. Several segments were laid down using a series of stills for a single digital audio event as a test to determine if the audio could be timed with the stills. The results demonstrated that the stepped stills with a single digital audio event worked well.

3. Would there be any blanking before each slide when the computer was grabbing the digital audio?

This question was not answered at the time the disc geography was designed. There was no straightforward answer as to whether or not the blanking would be significant between each slide when digital audio was being grabbed. To be cautious, the audio events were shortened for each slide to keep blanking to a minimum. The end result was more digital audio events in the program. Each digital audio event was laid down on the frame adjacent to the corresponding still frame. When the disc was finally mastered, the blanking between still frames was insignificant.

4. Can the user load a digital audio event, search to a motion segment, and play the event?

The answer is yes. There were a lot of activities in the EIDS EP which required a seamless transition from one audio event to another. This seamless transition was accomplished by fading out one event and fading up another. The digital audio was laid down before the fade-up of the next event.

5. How quickly can the digital information be downloaded into the computer?

The speed of downloading the digital information is related to the cache buffer, the amount of digital information to be downloaded, and the location of the Winchester image in relation to the segment that will be accessed. In order to shorten this time, all of the segments were laid out around the Winchester image, which was located in the center of the disc. The still frame segments were grouped together in order of their presentation within the segment. The audio events within a segment were short, in order to keep the cache buffer at eight frames or less. The motion was laid down in the first part and at the end of the disc. The majority of the still frames were laid down in one area, closest to the Winchester image. Since the motion segments did not require a tremendous amount of programming, they were put the farthest away from the Winchester image. This layout scheme did in fact reduce the downloading time. The average downloading of digital information for each segment took approximately two seconds. This digital information included the programming code, not the computer graphics. It took approximately 15 seconds to download 100 computer graphics into the computer memory.

6. Is it necessary to have any buffer around the digital audio or the Winchester image?

The answer is no. However, a black buffer was put before some of the digital audio events and around the Winchester image. This buffer provided the flexibility to change the digital audio events and the size of the Winchester image.

In summary, the major goal when developing the disc geography was to reduce access time. This was accomplished by putting the Winchester image in the center of the disc and having the courseware surround it. The motion segments were put at the beginning and at the end of the videodisc. All of the still frame segments were grouped together and laid out around the Winchester image. Frame 1001 was reserved for the DCF. There was some digital audio placed before frame 1001, but this was used for the diagnostic software in the ***EIDS EP***. It is not recommended that anything be placed between frame 1 and 1001 because of the physical anomalies of a videodisc. In addition, because of the likelihood that changes were going to be necessary to some of the audio and the digital information, black buffers (blank frames) should be left around the digital information (see Figure 5).

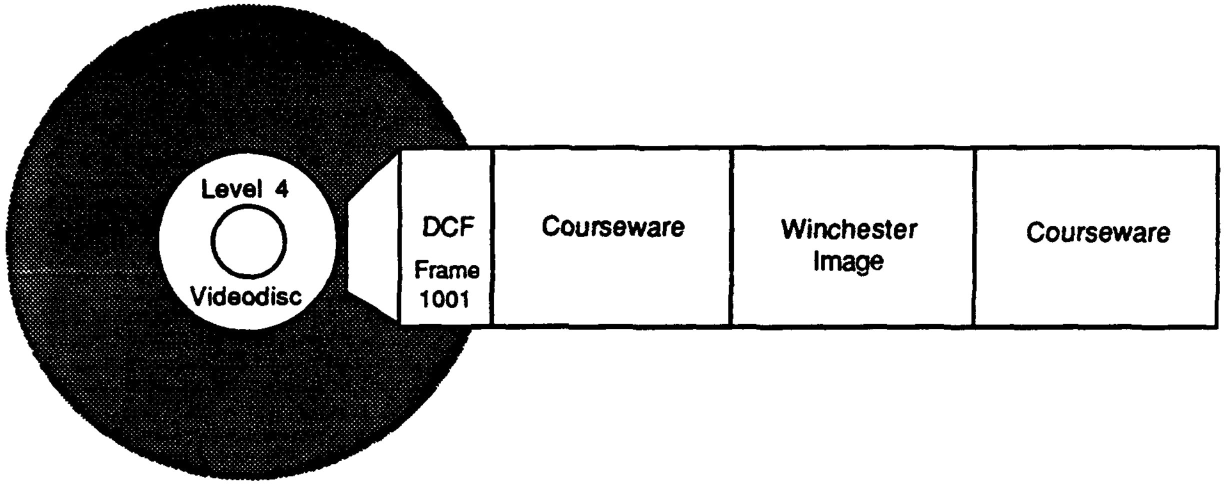

Figure 5. Level 4 Disc Geography

IV. AUTHORING ENVIRONMENTS

A. JUSTIFICATION FOR USING OASYS AND PILOTPLUS

After reviewing the requirements for the ***EIDS EP***, OASYS and PILOTplus were determined to be the best solutions for programming. EIDS ASSIST, the Army's authoring system, was not available when work began on the ***EIDS EP***. Although several authoring languages and systems were in the process of being ported to the new EIDS (including EIDS ASSIST), none was available that could fully exploit the benefits of Level 4. A substantial percentage of the programming power of Online Computer Systems, MetaMedia's parent company, was made available for the task (in-house) so that PILOTplus and OASYS could be completely ported to Level 4 as the project progressed, with a minimum of wasted time and communication breakdown. PILOTplus, due to the scope of this project, has become completely debugged for EIDS Level 4, as well as for all other levels of interactivity on the EIDS platform. Using another authoring system would have significantly increased the risk of delays due to software debugging.

As an authoring system, OASYS provided the tools necessary to quickly generate and debug the ***EIDS EP***. With OASYS, all of the graphics, the digital audio, and the video were easily cataloged and integrated in the program through the use of templates. Eight templates were developed that allowed a non-programmer to enter the information for each event in the script. Each template was designed to perform a different type of functions. Using these templates, an author was able to program 85 percent of the ***EIDS EP*** in five weeks time. In addition, consistency in screen design was maintained throughout the entire programming phase with these templates. All of the hard code programming was done in PILOTplus. These included all of the activities, the templates, and the bookmark feature. When the author was finished entering the information for each template, OASYS then took the information from the template and generated PILOTplus code. Using OASYS resulted in a significant savings in programming time (an estimated 10 weeks would have been required to custom code the ***EIDS EP***) and allowed changes to be easily incorporated into the ***EIDS EP***.

B. SPECIFICATION OF NECESSARY AUTHORING FEATURES FOR LEVEL 4

When developing the ***EIDS EP***, MetaMedia's design team found that in order for an authoring language or system to fully function on Level 4, it must have the following capabilities:

1. The ability to support digital audio from the disc without any breakup of the video signal; that is, without any digital audio being displayed on the screen when grabbed.
2. The ability to use all of the EIDS compatible interfaces (keypad, keyboard, lightpen, and touchscreen) to their fullest capabilities.
3. The ability to catalog all of the video, graphics, and digital audio events, and the ability to insert these events into the program easily.
4. The ability to execute outside programs.
5. The ability to play specific frames of a digital audio event.
6. The ability to design and display graphics in the various resolutions.
7. The ability to accurately overlay partial graphics over video.
8. The ability to use several fonts for text displays.
9. The ability to grab digital audio and play it over motion.
10. The ability to accurately time still images to a digital audio event.
11. The ability to grab digital data (Control Program) without any digital data displaying on the screen.

Although many authoring software packages have all of the above features, the critical criteria are ease of use and the ability to make changes or additions to the courseware. Additional criteria to be evaluated include: How structured is the authoring package? Is it necessary to follow certain guidelines in order to develop the courseware? Are these guidelines so strict that they compromise the courseware? An authoring language or system must be flexible and easy to use. It should allow for changes or additions, and not be so structured that it compromises the design. OASYS and PILOTplus are extremely flexible, easy to use, and provide the developer with several tools to debug and update courseware easily. OASYS uses templates that prompt a developer to fill in the required video, text, feedback, and branching information. Templates are programmed in PILOTplus and can be developed for many different types of interactions.

Performance is also an important consideration in making a decision on an authoring system or language. How quickly does the program respond to user input, and how quickly does the program grab the digital information from the videodisc and display it? EIDS ASSIST, at the time of this publication, takes a full one and one-half seconds of time before a touch is registered with the lightpen. In this situation, many users make the choice again, and perhaps even a third time. Lightpen hits are buffered in EIDS ASSIST. The net result is that the user has a backlog of lightpen hits which will be executed in sequence, causing confusion to a new user. OASYS and PILOTplus, on the other hand, have a well-designed light pen driver, one which gives the user immediate feedback when a lightpen hit is detected. This leads to a smoother, more responsive interaction with the courseware and is much less frustrating for the user.

There are many authoring languages and systems available for EIDS Level 3 development. However, there are only a few that fully work on Level 4. These include: EIDS ASSIST, OASYS, and PILOTplus. Icon Author™, SAM IV™, Ten Core™, Quest™, CEIT™, and IMSATT™ all work on Level 3-3.5 (digital audio, only) and most are now being upgraded to work on Level 4.

V. MANAGEMENT ISSUES FOR LEVEL 4 IVD

General Management Issues

There were several significant challenges that the MetaMedia team faced during the course of this project. These included the need for constant revisions, the costs of learning curves, and problems associated with production and software integration.

A. REVISIONS

In the development of any new product, a persistent problem during the development phase is the amount of change which the product undergoes before it is finalized for delivery. When developing an operator's manual that is directly tied to the product, these changes can cause major revisions of the design. In the ***EIDS EP***, these revisions were caused by a variety of factors, specifically:

1. Hardware Changes

During the first phase of this project, hardware was still under development. The Army required four additional versions of the EIDS hardware after the initial design document for the ***EIDS EP*** was written for only one version. The design document had to be completely rewritten and expanded to include the new versions of the hardware, extending the scope of work significantly.

Design strategies also had to be developed to deal with these four versions. These design strategies included multiple input devices and multiple versions of the hardware. Besides the additional versions, the basic hardware of the system, such as monitors, printers, and input devices was also changing. This precipitated further revisions to design documents and scripts, since they were tied so closely to the features and operation of these pieces of hardware.

2. Content Changes

Since the hardware was not ready to be shipped to MetaMedia until scripting had started, assumptions had to be made concerning the basic features and operation of the

EIDS equipment. It was very difficult to develop an operator's manual without the hardware on hand. Therefore, MetaMedia relied heavily on existing documentation from Matrox and the subject matter experts at Matrox. However, some of the information in the documentation underwent frequent revisions. Each time these revisions occurred in the documentation, changes had to be made to the design document and script. Some changes affected procedures, and nomenclature; others involved the addition or subtraction of component functions.

B. LEARNING CURVES

Any new technology requires time to learn its features, limitations, and pitfalls. Learning curves can be costly when the technology is so new that the developer also becomes the pioneer. Unfortunately, many projects do not factor these curves into the timelines and budgets. The ***EIDS EP*** project had several types of learning curves to deal with, specifically:

1. Hardware

There was a learning curve involved in understanding the EIDS hardware (about a total of three weeks). Time was needed to become acquainted with its various components and functions. This was especially true since the operator's manual (***EIDS EP***) had to be closely tied to the features, controls and indicators, setup, and operation of the hardware.

2. Level 4 Technology

This was the most difficult learning curve to overcome, primarily due to the lack of understanding of all of the elements of Level 4 technology. Beginning with the design and scripting phase, many strategies had to be carefully reviewed to determine if they were possible in a Level 4 environment. Such design strategies included: the user interface, the bookmark feature, branching, and screen layout designs. Each of these strategies was dependent upon how the digital information was managed and retrieved within a Level 4 environment. Since this was the first Level 4 application, there were no examples or models to build upon. Matrox had developed several Level 4 test discs that fully demonstrated EIDS Level 4 performance capabilities, but there was no precedent for the way a Level 4 application would work.

It was uncertain whether all the features the Army required for this ***EIDS EP*** would be possible. Therefore, the MetaMedia design team wrote the initial design document based on certain assumptions:

1. There would be enough memory available in a Level 4 environment to allow the bookmark feature to work effectively.
2. The graphics would be stored in an animation buffer.
3. There would be enough memory available to download the computer control program for each segment.
4. The digital audio could be used over a series of stepped-stills and motion segments.
5. Any digital information being grabbed from the videodisc would be invisible.
6. It would be possible to accurately time a series of graphics to appear during a digital audio event.

There was a high risk that one or more of these assumptions would prove to be incorrect. To reduce the possible impact of this risk, the most conservative approach was taken in the design phase, including:

1. Keeping the segments short. It was anticipated that this would reduce the amount of memory required to run each segment.
2. Keeping the digital audio events under eight frames (22.08 seconds).
3. Pairing each audio event with a single slide instead of a series of stills. There were certain sections in which, as an experiment, a series of slides over one audio event was used.
4. Placing much of the text and graphics on the videodisc instead of using graphic overlay. It was anticipated that this would reduce the amount of programming required for each segment.
5. Reducing the complexity of the user interface and the bookmark feature.

These steps helped ensure a feasible design, but they put more of a burden on the production aspect of the project. Since each digital audio event had a corresponding visual, more digital audio events were required. In addition, a substantial portion of the graphics and text was put on the videodisc, instead of being entered by the author during courseware programming.

C. PRODUCTION OBSTACLES

The production phase had its own obstacles to overcome. These included:

1. Digital Audio

At the beginning of the production phase, there was still some uncertainty concerning how digital audio would work on the videodisc. Unanswered questions at the start of the production phase included:

a. Would there be any blanking of video when the audio is being captured off the videodisc?

The answer is yes. The video blanking between each audio event is equivalent to a slide show (no more than one-half second).

b. Does digital audio have to be tied to a specific visual on the videodisc ?

The answer is yes. The videodisc head has to both capture the audio and display the visual. For this reason, the audio has to be specific to the frame which is being shown. For example, if the same visual appears for three different audio feedbacks, that same visual must be laid down on the videodisc three times. Each time, the visual will have its own unique digital audio event number. There is one exception to the rule. If a full screen computer-generated image appears on the screen, it is possible to randomly access digital audio on the videodisc.

c. Is it necessary to leave a landing pad before each digital audio event? The answer is no. It is not necessary to leave any landing pad before the digital audio event. Audio events can be placed back-to-back.

d. How much room must be left on the pre-master videotape for a digital audio event?

The answer depends on the level of audio quality being used. For the ***EIDS EP***, medium quality was used, and space for a digital audio event ranged from one frame (2.86 seconds) to 14 frames (40 seconds). The majority of digital audio events were under four frames.

e. How are these digital audio events cataloged?

Each digital audio piece in the script was given a unique event number. For example, the first digital audio event in the EIDS EP script was designated as "event #1," and each subsequent audio event incremented by one.

f. How are these digital audio events edited?

At the time that MetaMedia was ready to digitize the audio events, Matrox did not have an audio editor. (This is no longer the case.) Because this editor was not available, the MetaMedia production staff had to edit these events on the fly. When this was done, blank gaps in audio were added to the audio file. This extended the length of playback of the digital audio and made the presentation longer than it ideally should have been for each visual. With the new audio editor provided by Matrox, each digital audio event can now be accurately edited. In order to edit the digital audio, a pre-master authoring package would be required from Matrox. Matrox provides an audio editor in their authoring package. To use their editor, simply attach an audio source like an audio cassette tape player to the Pre-master board and run the digital audio editor. Before the audio can be digitized, a speed must be selected for audio quality (high, medium, or low). After the audio is digitized, it can be edited by moving the marker to delineate the audio to be saved (only 16 buffers can be loaded and edited at one time, for a maximum of 64 seconds of audio). Therefore, before any audio is digitized it must be broken into small audio events no greater than 16-frame buffers.

g. When audio events are digitized, is it possible to make one large audio file with an index of all of the digital audio events on the hard drive?

The answer is no. Each audio event is a separate file. Therefore, it is possible to have several hundred audio files on the hard drive.

2. Disc Geography

The primary challenge presented by the disc geography was to organize the videodisc for optimum disc access. Since little information about Level 4 disc access was available, a conservative approach was used. The Winchester image was placed in the center of the disc and the courseware was laid around this image. This approach allowed for all of the segments on the videodisc to be within equal distance of the Winchester image. The MetaMedia team found this approach to work extremely well.

3. Pre-mastering Specifications

Level 4 pre-mastering requires one-inch video equipment that completely meets NTSC specifications. This precision is an important consideration for Level 3 and Level 4 pre-master videotapes as outlined in the *3M Pre-Master Videotape Specifications*. However, this precision is even more critical for Level 4 because of the digital information that has to be encoded onto the pre-master videotape. Any excessive horizontal shift in video frame will render the digital information unrecoverable. This is why it is important to ascertain that the pre-mastering facility selected can edit a pre-master videotape that is plus or minus 10 deg SC/H phase, field one dominant, and will properly color-frame each edit before any editing is begun. This is especially important considering that Level 4 videodisc tends to have a large amount of single frame edits.

All videodisc manufacturers require the pre-master videotape to have a continuous control track from the first frame of tape lead-in to the last tape lead-out. SMPTE timecode (non-drop frame) must be continuous and incremental throughout the length of the videotape. Assembly editing will automatically break the control track and, for this reason, all pre-master videotapes use insert editing techniques (does not break the control track) instead of assembly editing.

Once all of the visual information on the pre-master is complete, the next phase is to lay down the digital information. This information can include both the digital audio and the Winchester image. Typically, a first check disc would contain the digital audio. To master the digital audio, Matrox recommends that a dub be made on the same one-inch machine on which the digital audio will be mastered. This will assure that the tape has a clean control track, and that there will be no horizontal or vertical shifts in the video frame. If a dub is not used, there is a chance that a vertical or horizontal shift in the video frame can occur when the digital information is being mastered onto the one-inch pre-master. This is related to the way a time base corrector (TBC) interprets the video signal from the pre-master videotape. Segments in the original edited pre-master videotape could possibly have bad edits, which could make the TBC "hiccup" and vertically or horizontally shift the video. This shift could be far enough to delete some necessary digital information in the video frame. If any digital information is deleted in the video frame, then the digital audio in that frame will not play back from the videodisc.

It is especially important that the one-inch machines have good TBCs to ensure the digital information is edited onto the pre-master tape at the proper color framing and SC/H phasing. A TBC that meets all NTSC specifications should suffice. If the TBC does not meet NTSC specifications, the digital data may not be able to be grabbed off the videodisc when it is mastered. Any major shifts in horizontal or vertical phase can cause the DCF frame to lose the digital information it needs to calibrate the videodisc to work as a Level 3.5 (digital audio only, all computer information is on the hard drive) or Level 4. If the computer cannot read the DCF frame, it will not be able to grab the digital information from the videodisc.

After the first check disc has been successfully mastered, the programming phase can begin. The control program is stored on the hard drive during development. Under program control the computer can now grab and play back the digital audio from the videodisc (Level 3.5).

4. Software Integration and Testing

Before authoring began, the scripts were reviewed and converted into programming scripts. This helped the transition from a production script to a script that could be used to author and program the ***EIDS EP***. At this point in the project, screen format standards were set and templates were designed.

The chief problem during the authoring and programming process was the fact that it was impossible to fully emulate a Level 4 environment. The only element of Level 4 fully available for testing was the capturing and playing back of the digital audio (Level 3.5) To fully test performance issues such as access speed, program flow, and the digital data capture, Matrox assisted in developing a facsimile to partially emulate a Level 4 environment. Using this facsimile, it became apparent that there were areas where the graphics mode was set incorrectly. The only drawback to the Level 4 emulation program was the fact that it could not show the actual downloading of digital information into the Digital Recovery (DTR) buffer. The DTR buffer is not used when accessing the digital information off the hard disk drive or floppy diskettes. Therefore, it was impossible to check the performance of the program operating under the Level 4 environment until after the second check disc was mastered.

The second problem in the software integration and testing phase was incorporating the EIDS Self-tests into the ***EIDS EP***. The Self-tests had to be memory-resident, and using about 175 kB of memory. When all of the drivers, graphics, and control program were loaded, there was not enough room left (about 25 kB of memory) to run a program of this size. PILOTplus was therefore modified to handle this problem. The Self-test program was treated as a separate part of the ***EIDS EP***, and to make the user interface consistent with the rest of the program, the EIDS Self-tests were run from a set of menus that are identical to the other menus within the program. This helped maintain a consistent user interface throughout the program. When a user quits the self-tests, this program is purged from memory and the ***EIDS EP*** program is loaded back into memory.

The major goal before the second check disc was completed was to locate any fatal errors that would cause the system to lock up and prevent the user from continuing with the ***EIDS EP***. In order to facilitate this, a debugger was developed. MetaMedia modified an existing debugger to track down any errors in the program during the quality assurance process. This debugger could be activated only by entering an eight-digit password at the beginning of the program. In the debugger, a number was displayed on the bottom of the screen corresponding to the lesson and unit numbers in OASYS. This feature made debugging the program easier. Problems with a section were coded by this number and noted.

Once this debugger was in place and the fatal errors were corrected, a second check disc was made. This check disc contained everything needed to operate in a true Level 4 environment. The Winchester image was mastered on the pre-master videotape. This was the first time it was possible to see how a Level 4 videodisc truly worked. To the delight of the MetaMedia team, the disc worked very well. Taking the conservative approach had proven to be the best route. The only obstacle remaining was to locate and fix bugs. This was a large task (about four weeks of effort) in a program that had over 2000 branches. Unfortunately, since a Level 4 videodisc is a read-only medium, bugs cannot be easily corrected after the videodisc is pressed. A magnetic update can be provided to fix any bugs, but this method should be avoided at all costs, especially in a mass distribution situation (8,500 copies) of a product like the ***EIDS EP***.

The only recourse was to find all of the bugs before the videodisc is pressed, an effort which required an extensive quality assurance program. This program included test scripts, bug report sheets, and a tracking system. The test scripts were used to follow all of the possible paths within the program. When an error occurred, the debugger provided a number which was used to locate and fix the bug. These bugs were documented in bug reports. These reports outlined the problem, listed the fix to the problem, and provided a record of who tested it, fixed it, and retested it to make sure the problem was corrected. Each bug report sheet was given a unique number and logged in a tracking system to ensure that these bugs were fixed and tested. These test scripts and bug reports allowed several people to thoroughly test and communicate the problems to MetaMedia. Working closely with Matrox and the Army, it was then possible to exercise the videodisc thoroughly and track down the remaining bugs before mastering the third, and final disc.

VI. COST ISSUES FOR LEVEL 4 IVD

General Cost Issues

Costing for any IVD project is tough to project accurately. Each IVD project is unique and has many variables which affect pricing. Therefore, costing issues addressed below are based on estimated effort for developing a Level 4 videodisc with the same complexity as the ***EIDS EP***.

In most cases, costing for project development is dependent upon time and materials. Time relates to manhours, and manhours are grouped into tasks for a given project. Because the process for developing Level 4 videodiscs is similar to Level 3, for the purpose of this discussion, tasks will be broken down into two categories: common tasks and additional tasks.

A. COMMON TASKS

These are tasks that are common to both Level 3 and Level 4 development; however, in Level 4, these tasks take longer to complete. The time that is needed to complete these tasks is proportionately related to the complexity of the Level 4 disc (see Figure 6). They include the following:

1. Design

In developing a detailed design document for a Level 4 videodisc, it is necessary to examine how the design strategies will work in this environment. There are certain aspects of Level 4 design that must receive careful consideration, such as memory management, user interface, and program flow. Consequently, an estimated 15 percent of additional time is required to take these elements into consideration. For example, if a Level 3 design takes 25 workdays to complete (18 percent of the total effort) then a Level 4 design will take 29 workdays to complete (16 percent of the total effort).

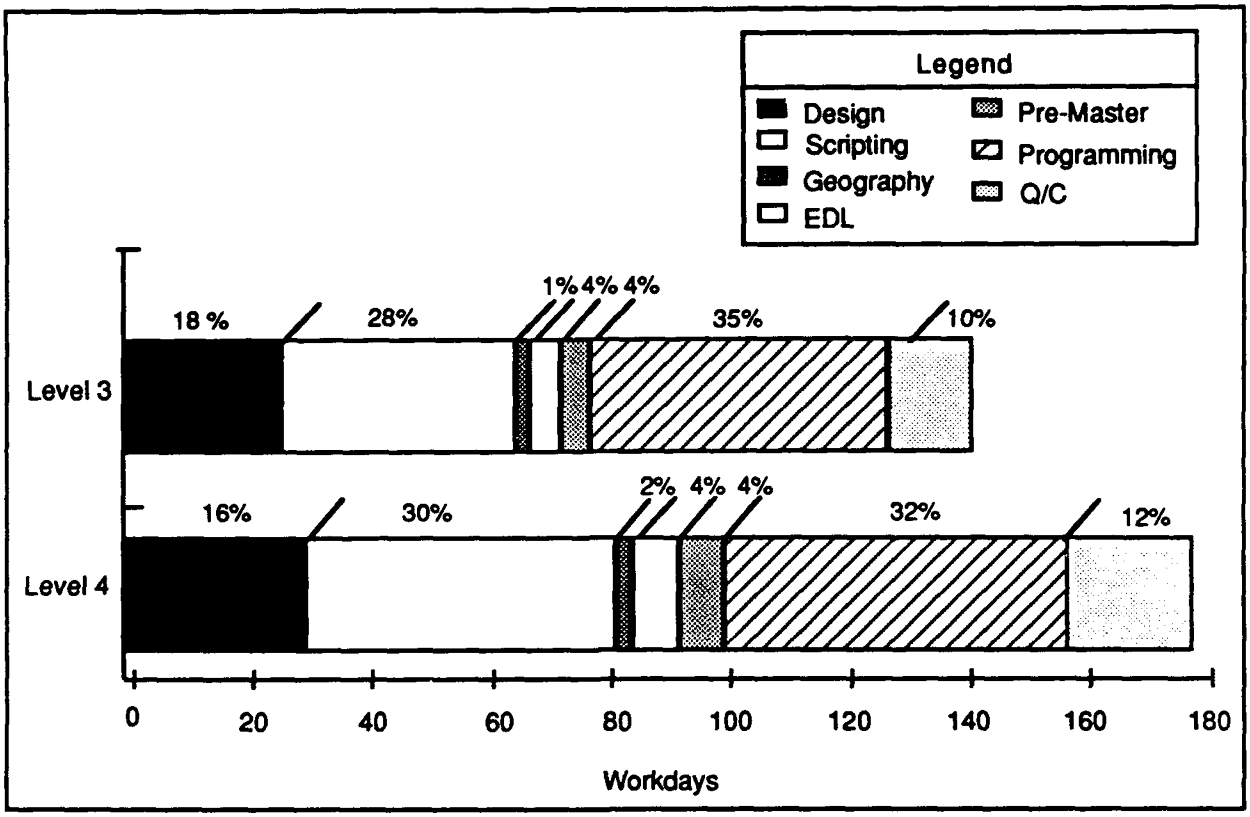

Figure 6. Common Tasks: Level of Effort for Level 3 versus Level 4

2. Scripting

Because the amount of information that can be stored on a Level 4 videodisc is so large, the scripting process is substantially extended. If digital audio is used in the script, it must be separated from the analog audio. In addition, it is necessary to determine exactly how the digital audio will be used. For example, it is possible to have one audio event played over a series of stepped-stills, or one audio event can be designated for each still frame. Memory management issues are an equally important consideration when developing a script. These issues include maintaining a maximum digital audio size (i.e., no greater than eight frames) and keeping the segments short enough to fit into available memory. This process takes about 30 percent longer than a Level 3 interactive script, especially in cases like the ***EIDS EP***, where there are several hundred digital audio events in a script. For example, if a Level 3 script takes 40 workdays to complete (28 percent of the total effort) then a Level 4 script will take 52 workdays to complete (30 percent of the total effort).

3. Disc Geography

Developing the disc geography for the pre-master videotape takes about 20 percent longer to develop for a Level 4 videodisc than for a Level 3. This is due to the large amount of information that can be stored on a Level 4 disc. As with any disc geography, the goal is to optimize the disc. In Level 4, this means finding the optimum solution to storing digital data, including placement of the Winchester image and considering how the digital audio events should be laid out on the disc. For example, it is possible to have several hundred images on the disc, each with a different digital audio event. Obviously, in cases such as this, there are a great many elements that must be considered. For example, if a Level 3 disc geography takes two workdays to complete (1 percent of the total effort) then a Level 4 disc geography will take three workdays to complete (2 percent of the total effort).

4. Edit Decision List

Because of the density of visual information on a Level 4 videodisc, the edit decision list can be many pages long (92 pages for the ***EIDS EP***). This list must be correct before any pre-mastering is begun. Considering all of the elements that must be logged, developing and checking this list can take up to 50 percent longer to complete than a Level 3 EDL. For example, if a Level 3 edit decision list takes 5 workdays to complete (4 percent of the total effort), then a Level 4 edit decision list will take 7.5 workdays to complete (4 percent of the total effort). It is important to take the time to make this list as precise as possible. It is better to correct a list before, rather than after, the pre-mastering process.

5. Pre-mastering

Once the edit decision list is completed, the next phase is pre-mastering. Pre-mastering is usually done in three phases on a Level 4 disc. During the first phase, all of the visuals are placed on the pre-master videotape. This phase takes about 50 percent longer to complete than a Level 3 pre-master. Editing a Level 4 pre-master is time-consuming, considering that a Level 4 videodisc can be composed of several thousand still frame images (the ***EIDS EP*** took 60 hours to edit). During the second phase, the digital information is placed into the black holes allotted on the pre-master. After the control program is complete, the third phase, pre-mastering the Winchester image onto the videotape, is begun. For example, if a Level 3 pre-master takes five workdays to complete

(4 percent of the total effort), then the three phases of Level 4 pre-mastering will take 7.5 workdays to complete (4 percent of the total effort).

6. Programming

During this phase, it is necessary to factor in time for the programmer to design the best solutions for the program flow. These solutions usually take into consideration memory requirements for the computer control program, the computer generated graphics, the capturing of the digital information, and the branching in a Level 4 environment (about 15 percent more time than Level 3). After these considerations are thoroughly reviewed, programming time for developing the computer control program for a Level 4 videodisc is the same as it would be for a Level 3 videodisc. For example, if a Level 3 takes 50 workdays to program (35 percent of the total effort), then a Level 4 will take 57.5 workdays to program (32 percent of the total effort).

7. Quality Control

Debugging the software is the time-consuming part of the programming process. It would take approximately 50 percent longer to debug a Level 4 videodisc than a Level 3 videodisc. The videodisc must be free from bugs before it is pressed. Therefore, it is necessary to allocate enough time in the budget for extensive testing and debugging of the software. It took one person three weeks to debug the *EIDS EP* software. The three weeks of time was broken into three one-week phases of quality control. The first phase occurred after the initial programming was complete. This phase checked how the program operated under a Level 3.5 environment. The second phase occurred after the second check disc. This check disc contained all of the digital information and operated as a Level 4 videodisc. The final phase of quality control checked the final Level 4 videodisc to make sure there were no remaining bugs before replication began. In summary, if a Level 3 takes 14 workdays to quality check (10 percent of the total effort), then a Level 4 will take 21 workdays to quality check (12 percent of the total effort).

B. ADDITIONAL TASKS

There are several tasks that are unique to Level 4 development. Again, these estimates are based upon developing a Level 4 videodisc of the same complexity as the *EIDS EP*. They include:

1. Digitizing and Editing the Digital Audio

Once all of the audio has been recorded, it must be digitized. When the audio event is digitized, it usually has to be edited. Since each digital audio event is a separate file, this can take anywhere from 24 to 40 manhours to complete. This is especially true when there are hundreds of digital audio events on a single Level 4 disc.

2. Developing the Digital Edit Decision List

When all of the digital audio is edited, a list must be developed to pre-master the digital audio events. This list is composed of all of the digital audio events and their corresponding places on the pre-master videotape. After the computer control program is written, the digital edit decision list is revised to include the Winchester image. However, the Winchester image is usually not mastered until the second check disc. Developing the EDL for a Level 4 videodisc can take up to 16 man-hours to complete.

3. Pre-mastering the Digital Information

Once the visual information is pre-mastered onto the videotape, the digital information can then be pre-mastered. This process can easily be automated with the pre-mastering software by Matrox. For the first check disc, the digital audio is usually placed on the videotape. This process can take from six to eight machine hours to complete, depending upon the one inch machine available. This time difference is primarily due to the differences in the transport mechanism among various machines (shuttle time). Only after the computer control program is written is the Winchester image placed onto the pre-master tape. This process can take anywhere from two to four hours. Preparations for this event include taking time to optimize the Winchester image, time to decide on the DOS configuration, and time to pre-master the Winchester information. This process should occur before the second check disc is made.

The second major element of project cost is materials. The only significant difference in material cost for Level 4 development is the additional check discs that are required during the development process. A minimum of two check discs is required to produce a Level 4 videodisc. The first check disc contains all of the visuals and digital audio. The second check disc contains the Winchester image and operates as a Level 4 disc. If there are any problems with the visuals or digital audio, another check disc may be required to verify any changes to be made to the pre-master. This is especially true if any of the computer overlay is directly tied to the video on the videodisc. We found that check discs made at 3M consistently work well. 3M does not charge any additional fee for mastering a Level 4 videodisc. Other manufacturers may charge an additional fee.

All of these additional man-hours in each task and the materials used to develop a Level 4 videodisc must be considered in light of the final product. Level 4 technology can store a vast amount of information on a videodisc. Because of this feature, it is possible to have several courses or one large course on one videodisc. The costs are greater to produce a Level 4 videodisc, but the storage capacity is also larger.

An additional factor that should be considered in costing out a Level 4 project is the cost savings in distribution. With a Level 4 videodisc, everything is self-contained on one medium. The user simply loads the videodisc and turns on the machine. The computer automatically boots the program right off the videodisc. Floppy diskettes are not necessary. Distribution costs can be considerably reduced in self-contained systems. For example, if the ***EIDS EP*** would have been delivered on a Level 3 videodisc, it would have been necessary to have five (720 kB) floppies and three videodiscs to run the course. The distribution costs for 8,500 copies would have been high. Figures 7 and 8 outline the cost for distributing the ***EIDS EP*** as a Level 3 videodisc and as a Level 4 videodisc. These costs are estimated and may be lower under government mastering and replication contracts.

In making a decision to produce a Level 4 videodisc, all of the costs and benefits of the technology should be taken into consideration. Not all applications are appropriate for Level 4 technology; for example:

- Applications in which the content changes frequently;
- Applications that require limited replication;
- Applications that must be developed under tight budgets and schedules; and
- Applications that have to be compatible with various hardware platforms.

However, there are applications that are appropriate for Level 4 (this assumes a large installed base of systems: 13,000 EIDS). They include:

- Applications that require more than a hour of audio per disc side;
- Applications that require large distribution for one or several courses; and
- Applications that require ease of installation of software.

Media	Quantity	Cost/unit	Total Cost
Videodiscs (2) 3 sides: 12 inch CAV	8,500	$27.54	$234,090.00
Floppies (5) 3-1/2 inch 720 kB	8,500	$10.00	$85,000.00
Packaging, Handling, and Shipping	8,500	$8.33	$70,805.00
		Total Cost ➡	$389,895.00

Note: Per-unit costs are calculated as follows:

1. ($3,600 + 1,800)/8,500 = $0.64 per unit for videodisc mastering
   $0.64 (Mastering) + $3.90 (Disc label and Case) + ($9.00 + $14.00) Replication = $27.54 per unit
2. $2.00/disk* 5 = $10.00 per unit for replication
3. $5.33(Packaging) + $3.00(Handling/Shipping) = $8.33 per unit for packaging, handling and shipping

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* The mastering and replication prices are based on 3M price list.

Figure 7. Replication and Distribution Costs for the *EIDS EP* as a Level 3 Videodisc

Media	Quantity	Cost/unit	Total Cost
Videodisc 1 sides: 12 inch CAV	8,500	$9.21	$78,285.00
Packaging, Handling, and Shipping	8,500	$3.90	$33,150.00
		Total Cost	$111,435.00

Note: Per-unit costs are calculated as follows:

1. $1,800/8,500 = $0.21 per unit for mastering
   $0.21 (Mastering) + $9.00 (Replication above 5,000) = $9.21 per unit for mastering and replication*

2. $0.65 (Custom Jacket) + $0.25 (Custom Label) + $3.00 (Shipping/Handling) = $3.90 for packaging, handling, and shipping

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* The mastering and replication prices are based on 3M price list.

Figure 8. Replication and Distribution Costs for the *EIDS EP* as a Level 4 Videodisc

VII. RESOURCES NEEDED FOR LEVEL 4 IVD

Based on the results of MetaMedia's experience in designing the ***EIDS EP***, the following recommended resources are needed to develop Level 4 IVD:

A. PERSONNEL

MetaMedia's design team included a program manager, an instructional designer, a script writer, a producer, a graphic artist, an author, and a programmer. The same personnel would have been required for a Level 3 project. However, unlike Level 3 development where different people work on the project during different phases of its development, Level 4 development requires the whole development team to work together from the beginning of the project.

All of the team members were involved during each phase of the project development. This created an easy transition from one phase to the next. The MetaMedia design team required substantial input from the programmer when designing and developing the ***EIDS EP*** script, in order to design the best approaches for memory and cache management within a Level 4 environment. These approaches included determining average digital audio lengths and finding the optimal memory requirements for each section. It is extremely important to finalize these approaches at the start of the design phase and not at the end of the scripting phase. If a script does not take these approaches into consideration, the program may not have enough memory available for each section to work optimally within a Level 4 environment, causing the program to be sluggish and choppy. A senior programmer should not be required for Level 4 development. Any programmer with at least two years of experience in programming IVD programs can read the EIDS Standard and EIDS Premastering Guide to understand all of the requirements for Level 4 programming.

Based on MetaMedia's experience, each member of a Level 4 design team should have the following qualifications:

1. Program Manager

Level 4 tasks take longer and require some additional tasks compared with those involved in a Level 3 program. A program manager should have at least three years of experience managing Level 3 IVD projects, since Level 4 projects are often "riskier" than Level 3 projects. This risk is due to the density and type of information that is on a Level 4 disc. Level 4 technology provides the capability to store several thousand visuals for one or several courses. If problems occur in the development phase, costs can climb rapidly. This is why it is important to have an experienced manager who is familiar with the technology and the process of developing a Level 4 disc. It is important to have a manager who has "the big picture" for the project and who can balance both the client's needs and the budget.

2. Instructional Designer

An instructional designer should have at least 2 years experience designing interactive courseware before attempting to design a Level 4 videodisc. This person should be familiar with interactive design and instructional design. This experience is necessary because Level 4 technology offers more challenges in design than Level 3, including such issues as large amounts of information, program flow, proper memory management, digital versus analog, and the user interface.

3. Script Writer

A script writer should be well versed in developing interactive scripts. Level 4 scripting requires scripts to be written in concise statements and with segments that are short enough to fit into available memory. A good script writer should not have any problem with developing scripts that flow well between segments, that are short enough to fit into memory, and that still communicate the intended thought.

4. Video Producer

A video producer should have a least two years of experience producing interactive videodiscs. A producer should have a good working knowledge of video, including a familiarity with proper procedures for single-frame editing, an understanding of waveform monitors and vector scopes, and a knowledge of procedures for developing a pre-master videotape for IVD. These issues are especially important when pre-mastering digital information onto videotape.

5. Graphic Artist

A graphic artist should be familiar with developing graphics for interactive media. This person should have a good understanding of PC paint packages for EGA and VGA graphics, a good understanding of developing screen designs using partial pictures, and a good understanding of developing a graphic "look and feel" for an IVD program. When developing a Level 4 videodisc, the creative use of graphics is very important. Graphics can be very memory hungry if they are not designed properly, and memory in a Level 4 environment has to be used sparingly. Therefore, a good graphic artist should be creative in developing approaches to displaying graphics in a Level 4 environment. MetaMedia's graphic artist designed all of the graphics as partial pictures. Partial pictures do not take a lot of memory to display; this approach allows the ***EIDS EP*** to have an active, pictorial user interface throughout the program.

6. Programmer

A programmer should have at least two years of experience programming IVD programs. This person will play a key role in the design and development of a Level 4 videodisc. If this person already has a good background in developing interactive courseware, then programming a Level 4 videodisc should not be very difficult. All the specific Level 4 information a programmer needs to know is clearly outlined in publications produced by Matrox.

7. Author

An author should have at least one year of experience in developing IVD programs with an authoring system. It is very important that an author have a talent for screen design. In Level 4 development, an author has to be especially accurate and detailed in authoring. This is important because all of the digital information is on the videodisc and cannot be easily changed if there are mistakes after mastering. Usually, if an authoring package is flexible and provides the tools to develop courseware for Level 4 IVD, then authoring should not be a problem.

B. EQUIPMENT

The equipment required to develop a Level 4 videodisc can be expensive. MetaMedia required an EIDS Version 3 with a 20 megabyte external hard drive, and a pre-mastering authoring system with an 80 megabyte external hard drive. Generally, when developing a Level 4 videodisc, an EIDS Version 3 or an EIDS Version 6 and a pre-mastering system with at least an 80 megabyte hard drive are required. This can cost around $18,500. The EIDS Version 3 is the old interlaced system with EGA graphics capability that comes with a full-size keyboard, a lightpen, and a 20 megabyte external hard disk drive. EIDS Version 6 is the new non-interlaced system with VGA graphics capability that comes with a full-size keyboard, lightpen, and an internal 40 megabyte hard drive.

For the video production, if an in-house studio facility exists, then purchasing a pre-mastering station for $13,000 may be the best way to go. If an in-house facility is to be used, it must have a good TBC and either a SONY or AMPEX one-inch machine. Generally, any facility that meets NTSC specifications can accurately master digital information onto the pre-master videotape. The pre-mastering (authoring) system is already configured to interface with the one-inch tape machine and comes with all of the required software.

If there is no in-house facility, or if the requirements are to digitize only the audio, a developer would need to purchase only the pre-master board from Matrox and the digital audio editing software. If equipment purchases are not feasible, a developer may choose to use the pre-mastering service offered by Matrox. This service includes mastering all digital information onto the pre-master videotape and it costs, at the time of publication, $1,000 a day. Once all of the audio is digitized and edited into files, it can be sent to Matrox. Generally, it takes about eight hours to master the digital information onto the pre-master videotape. This mastering time can vary; it depends on how the digital information is organized before it is given to Matrox and the quantity of digital information. Using this service can reduce the cost of buying a complete authoring station from Matrox (a savings of $6,500 in hardware).

C. SOFTWARE

MetaMedia's design team used several software packages to develop the ***EIDS EP***. These software packages included an authoring package, a programming language, pre-master software, a DOS compatible editor, a DOS compatible graphics editor, and some utilities. MetaMedia used OASYS as the authoring software and PILOTplus as the programming language. When selecting an authoring system or language for Level 4 development there are proprietary issues that need to be addressed. Many authoring systems and programming languages are proprietary and they generally require a site license, or run-time fee. Level 4 technology allows this software to be mastered directly on the videodisc and generally requires a licensing arrangement for any proprietary software used on the videodisc. This unforeseen expense should be considered before selecting a programming language or authoring software. Usually, software companies offer reasonable run-time fees. Examples of software that require such agreements is DOS, an authoring system or programming language, and programming *utilities. Similar* proprietary issues exist in Level 3 development. The only difference is that with Level 4 the software is located on the videodisc instead of floppy diskettes.

A DOS compatible editor like BRIEF™ or THE NORTON EDITOR™ are necessary for editing the programming code and developing the ASCII text files. MetaMedia used THE NORTON EDITOR™ to generate ASCII text files and edit PILOTplus code. The ASCII text files contain the Edit Decision List (EDL) for mastering the digital information onto the pre-master videotape. Regular text files generated by word processors contain control codes that confuse the pre-mastering software. However, word processors can generate ASCII text files. If an EDL for digital information is developed using a word processor, the document should be saved as ASCII text.

MetaMedia used NORTON UTILITIES, ADVANCED EDITION™ to optimize the hard drive and re-sort the directories. This was necessary before mastering the Winchester image onto the videotape. *Optimizing the drive is important in order* to reduce disk access time and develop a less cluttered DOS image. In addition, it is wise to sort the directories before transferring the Winchester image onto the pre-master videotape, as this can also reduce seek time and make it easier to track program modifications.

VIII. CONCLUSION

For the past ten years, there has been no standard universal delivery platform for IVD. Each hardware platform has had its own proprietary software and hardware. The only elements which have been standardized are the videodisc and the videodisc players. The lack of standardization has made it extremely difficult to design courseware for a mass market, because each system requires its own drivers and graphic standards.

The Army has made an initiative towards standardization by developing the EIDS platform. Every EIDS system has the capability to play a Level 4 videodisc, thereby allowing producers to deliver a self-contained product to a mass audience. Level 4 is a hybrid videodisc; it contains both digital and analog data. The density of information that can be stored, and the capability to run the program directly from the videodisc instead of a hard drive or floppies, make this technology very attractive for mass replication. Because there is now a standard courseware delivery system, the possibility of mass replication has become a reality.

Based on the experience of developing the ***EIDS EP***, MetaMedia believes that Level 4 is an intelligent choice when large scale replication is required. This technology is a stepping stone to the next generation of interactive media, whether it is DVI, CDI, or some other digital interactive standard. Until these new technologies mature, interactive videodisc will still be a contender among the various training technologies. We believe that Level 4 is an exceptionally viable transitory medium for the coming digital era.

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